Robots in the Ocean: Principles for Governance

Annie Brett

Introduction

A new robotic era in marine technology is here. In 2018, Finland ran the first trial of a fully autonomous passenger ferry, carrying members of the public on one of Finland's many sea routes. In 2019, Chinese fishermen picked up an unmanned, autonomous 10 foot vessel off of their coast. Equipped with sophisticated sensor equipment and enough solar panels to power the vessel across an ocean, this was an underwater drone presumed to originate from the US Navy to conduct surveillance on Chinese coastlines. It was not the first US Navy drone to be captured in China.[1] In 2020, IBM and Promare launched a modern version of the Mayflower, an autonomous vessel designed to cross the Atlantic retracing the route of the Mayflower and collecting scientific data.

This is the new landscape of ocean operations. From scientists to militaries to commercial enterprises, new classes of robotic technologies are rapidly expanding what it is possible to do in and on the world's oceans. Unmanned Maritime Vehicles (UMVs) are shattering many of the practical and economic limitations that have constrained operations on the ocean for centuries.

The legal questions raised by this evolution are significant, from whether Chinese fishermen who pick up a US Naval drone in Chinese waters have a right to possess this vessel to what safety and navigation rules an autonomous vessel has to comply with to whether marine drones should even be considered vessels to begin with.

Many of the issues facing maritime drones are the same as those faced by aerial drone use. Surveillance drones are being used throughout the world's oceans to carry out military, law enforcement and scientific missions.[2] Navies around the world are developing new classes of military drones that can launch missiles from unmanned platforms and engage in other types of offensive and defensive missions.[3] Commercial operators are increasingly looking to autonomous technologies as the future of their vessels, raising the very real possibility that much of global cargo shipping will eventually be on unmanned vessels.

Unlike the significant social and legal debates that has accompanied the increase in aerial drone use, there has been very little discourse about the increase in maritime drone use. Instead, academic and policy debate on marine robotics is focused on highly technical questions of how

[1] Harriet Agerholm, *China Seizes US Navy Underwater Drone in Interna- tional Waters of South China Sea*, INDEPENDENT (Dec. 16, 2016), http://www.inde- pendent.co.uk/news/world/asia/china-seize-us-navy-underwater-vehicle-south-china- sea-one-china-taiwan-a7480016.html.

[2] *See* NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE, *Leveraging Unmanned Systems for Coast Guard Missions* (2020).

[3] ERICH C FRANDRUP, *Embracing Underseas Robots: A US Strategy to Maintain Undersea Superiority in an Age of Unmanned Systems* (2021).

to convert safety regulations to accommodate different types of marine robotics.[4] Discussions around the regulation of marine robotics are heavily focused on compliance with existing marine safety laws. This is a stark contrast to the debates around the widespread use of aerial drones or other types of robotic interventions, which implicate important constitutional and ethical questions.

Marine robotics bring up the same questions, but these are largely ignored in the race to work out the logistics of complying with maritime safety regulations. This is a myopic view. Ensuring UMVs achieve safety goals is critical but focusing on safety to the exclusion of other legal questions will fundamentally undermine the successfulness of UMV regulation and not adequately address the issues presented by burgeoning marine robots. UMVs are reshaping the landscape of what is possible in the marine environment and raise questions that our current regulatory framework is unable to effectively answer.

This paper takes a step back, asking how the advent of widespread UMV use is altering interactions with the ocean and what questions this raises for national and international legal regimes. Part I begins by describing the landscape of UMV use across the oceans. It notes that while the majority of policy attention is focused on the advent of large, commercial shipping UMVs that may begin operation in several decades, there are already many other types of UMVs in regular use. Part II lays out the regulatory frameworks that form the foundation of UMV governance and discusses various proposals at the US and international levels to regulate UMV use going forward. It then goes on to identify gaps in current and proposed governance models that need to be addressed for UMV regulation to be successful. Certain areas of UMV operation will be well-covered by modifying existing rules, for instance in the areas of safety. This paper focuses on identifying where existing regulation will fail to cover the impacts of UMV use, highlighting these as core gaps that new regulatory schemes must address. Part III concludes by drawing on these gaps to identify core principles that should form the basis of future UMV regulation.

Part I: The current landscape of ocean robotics

Humans have been using robots in the ocean for nearly a century out of operational necessity. Tesla's first tests to remotely control objects were done on small boats in 1898.[5] Since then, commercial, scientific and military operations have relied on small robots to carry out tasks that humans were unable to do. These historically were primarily tethered to larger vessels and remotely operated, known as Remotely Operated Vehicles (ROVs). The advent of more sophisticated technologies in the last decade has allowed these vehicles to ditch their tethers

[4] *See e.g.* Henrik Ringbom, *Regulating autonomous ships—concepts, challenges and precedents*, 50 OCEAN DEV. INT. LAW 1 (2019); Craig H. Allen, *Determining the legal status of unmanned maritime vehicles: Formalism vs functionalism*, 49 J. MARIT. LAW COMMER. 477 (2018).

[5] G. R. Shaw, *The Rise of the Predator Empire: Tracing the History of U.S. Drones*, UNDERSTANDING EMPIRE (2014), https://understandingempire.word-press.com/2-0-a-brief-history-of-u-s-drones/.

and travel freely around the oceans. This has dramatically expanded what ocean-going robots can do.

There are many different definitions and naming conventions for marine robots (a foreshadowing of the fragmented regulatory approach applied to marine robotics). Different organizations often use their own definitions of marine robotic systems, with one report on the area finding 27 commonly used acronyms to describe these types of systems.[6] In this article, I use Unmanned Marine Vehicle (UMV) broadly to include a variety of different types of marine robots that share the defining characteristic of being able to move around the ocean while unmanned by human crew.[7] UMV includes vehicles operating in all areas of the ocean, both Unmanned Marine Systems (UMS) or Unmanned Surface Systems (USSs) and Unmanned Underwater Systems (UUS).[8] I also include within the broad UMV definition both UMVs that fit that legal definition of a vessel and those that do not.[9]

UMVs can be operated completely autonomously or remotely controlled. Most UMVs are somewhere in the middle of this spectrum, with the ultimate aim to make many of them autonomous. Passively powered drifting platforms for instance, are not autonomous but are capable of collecting data on their environment on programmed schedules, putting them more in the category of automated.[10] How much autonomy a UMV has has legal implications for how UMVs are regulated, particularly under COLREGs. It also has implications for whether a UMV can be fairly called a robot- remotely operated UMVs likely do not meet the classic definition of a robot. However, many of the regulatory issues surrounding UMVs are the same regardless of how autonomous the vessel is.[11]

When a vessel is unmanned is also open to some debate. For vessels without any humans onboard the distinction is clear. In many cases though, human crew may remain onboard larger ships in particular in some capacity to make repairs or provide other types of support, even if they are not involved in steering the vessel. In these cases, the legal distinctions may turn not solely on whether a vessel is manned or unmanned, but where crew are physically located on a vessel and what their operational role is.[12] I interpret unmanned broadly here to include situations where vessels are either periodically unmanned or operating autonomously without

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[6] National Academies, *supra* note 2, at 154.
[7] Notably, this paper also focuses solely on unmanned vehicles, not the many robotic technologies that may be use onboard existing vessels to improve operations in various ways.
[8] National Academies, *supra* note 2, at 30.
[9] For more on this distinction, *see infra* Part II.
[10] National Academies, *supra* note 2, at 31.
[11] Where this is not the case, for instance surrounding COLREGs lookout requirements, I discuss this distinction in greater depth. *See infra,* Part II.
[12] *See* Ringbom, *supra* note 4, at 3 (noting that "The level of manning, for example, is to be separated from the location of the crew… Some legal hurdles manifest themselves as soon as the watchkeeping officer leaves the bridge unmanned, even for a very brief period of time, while other requirements, such as the duty to have a master or a ship security officer on board, can—in theory at least—be met as long as a single crew member remains on board the ship.")

humans in the loop. This is distinct from vessels that are manned with monitored autonomy, which are much easier to incorporate into existing legal regimes.[13]

The heterogeneity of definitions reflects the many different ways autonomy and robotics are currently being used in the marine realm. While the majority of attention legally has been focused on the possibility of completely autonomous ships, in practice hybrid systems that include some degree of human oversight are currently much more common and will likely to continue to be so for the near term.[14] This creates interesting regulatory challenges, as effective regulation must be able to deal with the many different variations in how autonomy is being implemented and UMVs are being used.

This section lays out the landscape of current UMV operation in the oceans. While the majority of commercial and policy attention has been on planning for the advent of large, autonomous cargo ships, in practice this is just a small fraction of UMV use. It will likely be decades before autonomous cargo ships are roaming the ocean, in the meantime, many other types of UMVs are already in regular use and raising legal questions that few have focused on addressing.

A. Scientific UMVs

Robots are an essential tool for ocean scientists. Scientists have been using different types of marine robots to explore and learn about otherwise inaccessible ocean ecosystems for decades. Robots have enabled the discovery of entire new communities of life, such as those around deep sea vents. Today's scientific robots are breaking new ground, expanding the range of what it is possible to observe and discover in the oceans. This information is essential for better understanding ocean ecosystems and informing global management decisions.

The majority of robotics currently being used in the oceans today collect baseline information on ocean conditions. This *in situ* data in the past was primarily collected by fully staffed research vessels, of which there are only a small handful globally. Time and money constraints meant that data was only collected on small portions of the ocean, leaving scientists with relatively little information about vast swaths of ocean ecosystems.

Ocean scientists are still inherently limited by the sheer size of the ocean, but new robotic technologies are rapidly improving our ability to gather critical baseline data on more of the world's oceans. Many scientific floats are already deployed throughout the world's oceans. These are small sensor platforms that drift with global currents, sending information to shore at regular intervals via satellite.[15] The ARGO program, for example, has roughly 4000 profiling floats deployed around the globe at any given time, with an additional 500 launched each year to replace old units at the end of their life.[16] Argo floats and other similar systems have dramatically

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[13] *Id.*

[14] Ringbom, *supra* note 4, at 5.

[15] *See* Katharina Bork et al., *The legal regulation of floats and gliders - In quest of a new regime?*, 39 OCEAN DEV. INT. LAW 298, 299 (2008) (noting that a float is " an autonomous vehicle used for collection of [. . .] data [. . .] and floating passively…").

[16] *Argo's Status,* ARGO, https://argo.ucsd.edu/about/status/.

improved scientific understanding of global marine ecosystems in the 20+ years they have been active.[17]

These observation platforms are becoming more sophisticated, moving from simple drifting floats to passively powered robots that are able to move independently of ocean currents (albeit slowly). These UMVs rely on propulsion driven by wave, wind or solar energy to stay at sea for up to years at a time. During this time, they can travel and collect data across entire ocean basins.

Two of the most advanced ocean robots, Wave Gliders and Sail Drones, are already being used to collect oceanographic data globally. Wavegliders, built by Liquid Robotics, pair solar and wave energy and can operate autonomously or be controlled through satellite links. These devices are able to deploy sophisticated scientific arrays at depth by combining a surface vessel with an attached sensor payload 20 feet below. SailDrones are wind-powered robots with similar capabilities and technical specifications. In the past decade of development, these drones have covered over 500,000 nautical miles. Large scale deployment is in the works, with both scientific and law enforcement organizations beginning to use these robots.

A slew of other marine scientific robots are in the development stages, with many organizations incentivizing the creation of new, more sophisticated types of UMVs. XPrize, for instance, launched a competition to incentivize the development of UMVs capable of high-resolution seafloor mapping.[18] The winning vessels are beginning to be used globally, contributing important data to new international efforts to fully map the world's seafloor by 2030 as part of the 2021-2030 UN Decade of Ocean Science for Sustainable Development.

Robots are also being used in conjunction with existing research vessels. Tethered submersible remotely operated vehicles (ROVs) have been used for decades to complement research vessel capabilities. ROVs are particularly important for exploration of deep-sea ecosystems. Some organizations are transitioning to untethered ROVs or autonomous underwater vehicles (AUVs) as a way to expand the operational scope of these robots.

The explosion in scientific UMV use is a paradigm shift for oceanographic research, which in the past has been primarily conducted on research cruises that are extremely limited in geographic scope and temporal coverage. UMVs can cover more ground much more cost effectively and already are contributing data on ocean ecosystems that is critical in further scientific understanding of these areas as well as informing global models of climate change.[19]

B. Commercial UMVs

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[17] Dean Roemmich et al., *The Argo Program: Observing the global ocean with profiling floats*, 22 OCEANOGRAPHY 34–43 (2009).

[18] This prize interestingly was funded by Shell, presumably either for PR purposes or because it is interested in ultimately adopting these developments in their own commercial efforts to better explore, and exploit, ocean resources.

[19] *See e.g.* Lijing Cheng et al., *How fast are the oceans warming?*, 363 SCIENCE (80-.). 128–129 (2019).

The commercial maritime industry has long relied on robots for their operations. From inspecting oil platforms to repairing deep-sea cables, robots enable operations in environments that are very difficult or impossible for humans to reach. Historically, these robots primarily were Remotely Operated Vehicles (ROVs) tethered to ships and operated remotely. Today with the advent of automated and fully autonomous software, these vehicles are much less likely to be tethered and instead operate freely. These increased technological capabilities are not just improving current operations, they are enabling entirely new spheres of maritime commerce.

Shipping

Of all ocean industries, the shipping industry has the potential to see the greatest changes with the advent of unmanned, autonomous shipping vessels. The breadth of impact this shift would have on global maritime industries is staggering and the majority of UMV discussion by policymakers and industry members has been on this sector. The majority of global trade in goods is supported by marine shipping, with over 11 billion tons of cargo a year transported at sea on over 100,000 vessels.[20] Shipping is a relatively inexpensive way of transporting goods around the world, but the cost of paying human crews (and the resulting injury claims that accompany them) is significant enough that the world's large shipping companies are almost universally investigating the potential for autonomous ships to replace traditionally crewed vessels. Converting existing ships to fully autonomous ones may save companies between 4-11% in operational costs, while reducing carbon emissions by as much as 20%.[21]

In many ways, the shipping industry is ripe for a transition to autonomous vessels in a way that many land-based sectors, for instance cars, are not. The ocean is a relatively uncrowded operational environment, making AI use easier than navigating through complex cities. Ship crews today already use autopilot systems nearly all of the time to steer the ship. These systems can pilot the vessel between fixed GPS waypoints and in some cases are sophisticated enough to avoid major weather systems or other obstacles along the way. Creating fully autonomous vessels will require building out these systems considerably, but in many cases the technical and mechanical foundations for self-steering is already in place.

Some also point out that moving to autonomous ships may decrease existing safety problems in the shipping industry. Proponents of autonomous technologies note that by some estimates, up to 85% of collisions at sea are caused by human error.[22] Automation may reduce the likelihood of these types of errors, though will increase other types of errors introduced by technical failure or inability to fix systems problems when humans are not physically onboard.

[20] UNCTAD, REVIEW OF MARITIME TRADE 1, 36 (2020), https://unctad.org/system/files/official-document/rmt2020_en.pdf.

[21] OneSea, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0022.

[22] Andrzej Felski & Karolina Zwolak, *The ocean-going autonomous ship - Challenges and threats*, 8 J. MAR. SCI. ENG. (2020).

The hurdles for autonomous shipping vessels come when vessels approach land. Ports are operationally complex bottlenecks with unique and changing local characteristics that are difficult to program. Ports are so difficult to navigate even for human mariners that all large vessels are required to bring local pilots on board to steer ships into harbor. Current discussions of autonomous shipping vessels often rely on a similar system, planning for vessels to cross ocean basins autonomously and then be guided into port by human pilots (either remotely or on the vessel itself).

The other major hurdle for autonomous shipping vessels is the sheer difficulty of maintaining systems in the marine environment.[23] Shipping vessels today employ as many engineers as they do mariners whose job is to steer the boat. These engineers are needed to maintain and fix engine and mechanical systems when they inevitably break. A conversion to fully autonomous shipping will require not just AI that can steer a boat, but improvements in the mechanical infrastructure that allow the ship to either fix itself or be fully redundant if and when systems fail. If communication infrastructure breaks down or the AI command system itself fails, there will be little way to effectively ensure that these vessels are able to return to shore. The consequences of either mechanical failure or failure of the control systems are high: the ocean is very large and reaching any stranded vessel to make repairs could take weeks. These failures happen not only out at sea but also when approaching ports, raising the risk to other people and property. The port of LA alone sees 1-2 breakdowns a month in their waters, breakdowns that must be handled quickly and effectively to prevent major accidents.[24] For this reason, most companies imagine that autonomous cargo ships will be attended by a skeleton engineering crew for the foreseeable future.

The International Maritime Organization has proposed four major categories for classifying Marine Autonomous Surface Ships (MASS) that takes into account the heterogeneity of implementation. The lowest level of autonomy uses AI decision support tools on crewed vessels. This is already happening commonly around the world, with AI systems helping to steer and route ships with human oversight. Degree Two vessels are remotely operated but still crewed, while Degree Three vessels are remotely operated and uncrewed. Neither of these types of ship are used commercially, though they are being tested. Degree Four vessels are fully autonomous. Fully autonomous vessels are now being widely tested and have in limited cases been used in commercial applications. For instance, Finland ran an autonomous ferry on one of its passenger routes as early as 2018.[25]However, despite being capable of being "fully autonomous," these vessels are still operated with crew in these testing phases.[26] Legal questions around unmanned,

[23] GMATEK, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 12, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0019.

[24] Marine Exchange of Southern California, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (Oct. 14, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0032.

[25]Notably, while the vessel did operate in autonomous mode, there were crew onboard to oversee the system and sure the trial proceeded successfully. Felski & Zwolak, *supra* note 22.

autonomous vessels are likely to hamper widespread use of Degree Four vessels for the near future.

While the US has been a leader in UMV deployment in the defense sector, Europe and Asia lead the way with commercial UMV efforts. The EU recently committed nearly 30 million Euros to the Autoship project, which aims to build and launch two autonomous cargo vessels operating in nearshore European waters in the next several years.[27] The major shipping companies are all putting significant resources into developing autonomous technology. Early focus areas for autonomous shipping are in tugboats and general near-shore routes.[28] The promise of autonomous vessels is even more attractive after the impacts of COVID-19 on the shipping industry and the attendant issues with crew stranding around the world.[29]

The importance of autonomous vessels for the commercial maritime sector has led major maritime training academies to begin UMV specific training programs. Maine Maritime Academy, for example, has started one of the first of these, complete with a test UMV for students to use.

The move to UMVs to replace cargo shipping is a significant one, but one with many logistical and regulatory hurdles to overcome before it is implemented widely. This is a process that will likely take decades.

<u>Industrial</u>

Other commercial maritime industries are also increasingly turning towards robotics for future operations. Oil and gas drilling industries have long used robots to carry out drilling and extraction. Offshore drilling rigs use robots to inspect underwater equipment. Historically, ROVs have been used for this purpose in combination with commercial divers. ROVs are limited in their ability to interact with existing infrastructure and make appropriate modifications on repairs. Divers are called to do more complicated underwater repair work. Commercial diving on drilling rigs is extremely dangerous, often requiring saturation dives that keep divers underwater for weeks at a time in submersible habitats. This is costly as well as extremely dangerous. Improved UMVs may be able to take the place of human divers in many cases, lowering costs and increasing efficiency and inspection coverage.

The oil and gas industry as well as other extractive uses, namely mining, are increasingly relying on robots to carry out surveys. High resolution mapping of seafloor geology is necessary to determine where key resources are located. This in the past has been done with ships. Now, robots are able to cover far larger areas with less resource investment.

Robots are also enabling new types of extractive marine industries. Deep sea mining, for example, has only become commercially viable with the advent of highly sophisticated marine

[27] Felski and Zwolak, *supra* note 22.

[28] American Bureau of Shipping, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 12, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0027.

[29] *Id.*

robotics. Deep sea mining targets rare earth minerals that are located in nodules on the seafloor, often thousands of meters deep. These include many rare earths that are critical components in batteries, such as cadmium. In the past, steady terrestrial supplies of these elements combined with the technical difficulty of reaching these deep-sea areas has prevented deep-sea mining from taking place. The current explosion in demand for batteries is projected to lead to shortages in key rare earths that could be filled with deep-sea minerals. New companies are developing robotic technologies that will be able to descend to the seafloor in extremely deep areas and harvest nodules. These robots will pioneer commercial operations in areas that have so far been simply impossible to operate in.

The last large maritime industry is fishing. Like extractive industries and transportation, robots are being increasingly relied on by the fishing industry to carry out existing operations. Unlike in shipping, there has been little effort put into creating fully autonomous fishing vessels. There are myriad reasons for this. Fishing is a much more complex process than cargo transportation, which is largely a matter of going from point A to point B. Fishing requires identifying potentially successful locations, stopping frequently, deploying gear and bringing fish on board. Additionally, fishermen are needed on boats to ensure compliance with regulations by only bringing on board target species and releasing any bycatch or protected species back into the ocean. Doing these tasks well is currently beyond the technical capabilities of any UMVs and it will likely continue to be for the foreseeable future.

However, the fishing industry is increasingly turning to robotic and autonomous technologies to augment human crewmembers. Bringing autonomous technologies to the fishing industry has the potential to dramatically reduce injury and accidents onboard fishing vessels, which are some of the most dangerous jobs in the world.

In particular, Electronic Monitoring (EM) technologies are increasingly being used onboard fishing vessels. EM places video cameras onboard vessels and is primarily a regulatory tool to ensure that fishing vessels are complying with existing fisheries laws. Video surveillance data from EM is sent to shore, where it is analyzed with AI to determine violations. Future versions of EM may rely more on active robotic elements. For instance, some proposals include placing video cameras underwater that can identify when non-target or protected species enter fishing nets and automatically trigger a safety mechanism in the net to allow these species to swim free. This is a long way from being operationally viable.

Outside of wild-caught fisheries, robotics use is also emerging in aquaculture. Aquaculture is a rapidly growing industry and one that many look to as an essential source of protein for a growing global population. In particular, efforts to successfully farm large pelagic species are increasing. These open ocean aquaculture facilities are notoriously difficult to operate because of their distance from shore, making maintenance and feeding operations lengthy. To date, open ocean aquaculture facilities have only been trialed in a few locations where access to ports is easy and weather patterns are calm enough to allow boats to go out to the facility nearly every day. Robotics has the potential to expand what is possible with these aquaculture facilities and where they can be sited.

C. Government UMVs

Militaries globally have already been early and rapid adopters of UMV technologies, with some arguing that the next chapter of marine warfare is an "age of unmanned systems."[30] The US and China are leading this charge, with China also investing heavily in developing both offensive and defensive UMVs.[31] The military has long had creative approaches to gathering information about ocean environments. Various militaries use dolphins and other marine mammals to do a range of mission's underwater, from detecting mines to gathering information. UMVs add to this operational capacity.

The US Navy has been a pioneer in autonomous vessel technology and other types of marine robotics, adopting a UMV strategy as early as 2007.[32] These vessels are being used for all types of operational roles, from mine clearing to information gathering to surface warfare. The size and type of Naval UMVs ranges significantly, from full ship size UUVs such as SeaHunter, which completed its first voyage from California to Hawaii in 2018,[33] to smaller information gathering platforms.[34]

While the US Navy has been a heavy investor in autonomous technologies, the US Coast Guard has not.[35] The Coast Guard currently has some aerial drones in active use and is testing other types of UMV technologies.[36] To date, the Coast Guard approach to autonomous technologies has been relatively underfunded and ad hoc.[37]

The benefits to the Coast Guard of expanding marine robotic use are notable. Many of the Coast Guard's missions require huge expenditures of resources to reach distant areas of the ocean. Robotics could supplement existing capabilities particularly in reaching these distant areas and helping to conserve resources.[38]

For instance, Search and Rescue at sea is limited by geography: many of the calls for help that occur are from boats thousands of miles from shore. Reaching these vessels can take days or weeks for the nearest ship. US Coast Guard and other military assets use planes to reach vessels in distress, but are limited in the types of assistance they can provide. Search and rescue UMVs

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[30] FRANDRUP, *supra* note 3.
[31] *Id*, at 3.
[32] NATIONAL ACADEMIES, *supra* note 2, at 71, 75.
[33] Scott Trevithick, *Navy's Sea Hunter Drone Ship Has Sailed Autonomously To Hawaii And Back Amid Talk Of New Roles,* THE DRIVE (Feb. 4, 2019), https://www.thedrive.com/the-war-zone/26319/usns-sea-hunter-drone-ship-has-sailed-autonomously-to-hawaii-and-back-amid-talk-of-new-roles.
[34] NATIONAL ACADEMIES, *supra* note 2, at 74.
[35] *Id.,* at 7.
[36] *Id.*
[37] *Id.,* at 62.
[38] *Id.* at 85.

could dramatically improve rescue capability, stationing UMVs throughout the ocean that are able to quickly respond in the case of emergency.[39]

The Coast Guard's relatively small budget means that they strive to be a "fast follower" in regards to technology adoption.[40] This directly contrasts with the US Navy, which is directly funding and leading autonomous system development. In addition to contracts with purpose built UMVs, several companies have developed software systems that can turn any vessel into an autonomous platform.[41] The Coast Guard is beginning to use these systems on some of their existing smaller vessels.[42]

The Coast Guard is also using new robotics specifically for operations under the ice in Arctic.[43] A strategically important area with competing claims from Canada, Russia and the US that is seeing a rapid expansion in commercial and recreational traffic, vessel operations in the Arctic have long been difficult. Initial UMV deployment to the area is focused on preparing for oil spill detection and response, though other capabilities are likely to come online in the future.[44]

The Coast Guard and maritime law enforcement agencies globally will benefit from increasingly sophisticated and cost-effective UMVs. In addition to their operational roles, UMVs can be used as a deterrent: having more visible law enforcement presence may prevent certain types of illegal activity.[45] UMVs are also being used to support environmental protection missions by enforcing existing protected areas and no-take fisheries zones. In the future, they may be used to respond to oil spills or ether emergencies in dangerous operational conditions.[46] NOAA uses marine robots for a variety of management missions, from data collection to emergency response.[47]

On the other hand, illegal actors are also increasingly using marine robotics to evade law enforcement. Illegal submarines have long been used for drug trafficking, as they are relatively difficult to detect. Improving these to make them unmanned vastly increases potential success for traffickers. Marine robotics are also being used to interfere with law enforcement operations, through physically interfering with and distracting Coast Guard vessels or by jamming communication frequencies.[48]

D. Recreational UMVs

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[39] SCOTT SAVITZ, AARON DAVENPORT & MICHELLE ZIEGLER, *The Marine Transportation System, Autonomous Technology, and Implications for the U.S. Coast Guard* 1, 6 (2020).
[40] NATIONAL ACADEMIES, *supra* note 2, at 29.
[41] *Id.* at 54 (describing the Spatial Integrated Systems' Multi Agent Robotic Teams Autonomy System).
[42] *Id.*
[43] *Id.,* at 55-57 (2020), https://doi.org/10.17226/25987.
[44] Interestingly, the Coast Guard anticipates some of the cost of development of oil spill detection UMVs to be recouped from the legally responsible party in the event of an oil spill. NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE, *Leveraging Unmanned Systems for Coast Guard Missions* 1, 55 (2020).
[45] *Id.*
[46] SAVITZ, DAVENPORT, AND ZIEGLER, *supra* note 39, at 7.
[47] NATIONAL ACADEMIES, *supra* note 2, at 78-79 (2020).
[48] *Id,* at 6.

Robots are not new to many sectors of the marine world, but their availability to members of the general public is a completely new development. In the past, marine robotics have been prohibitively expensive, limiting their use to sophisticated and well-capitalized commercial and defense organizations. The advent of low-cost, open-source technologies is changing this.

Many low-cost tethered UMVs are now available to the public. These are equipped with sophisticated camera equipment and allow users both to look in real time at what is happening underwater as well as to record video footage for later use. These UMVs are also being used by schools for educational purposes and by environmental non-profits and others to identify and remedy ecosystem degredation. The Rosalia Project, for instance, uses OpenROVs to find and clean up marine trash. OceansWide similarly relies on robotics to find derelict lobster traps and remove them from coastal areas of New England.

While low-cost robots are expanding access to the oceans, many wealthy individuals are also developing their own marine robots. Some of these have environmental conservation goals, such as the Ocean Cleanup. Others are mainly for exploration, sometimes with a scientific gloss, like the UMVs associated with Ray Dalio's OceanX. Bill Stone's Sunfish AI is intended to push cave exploration boundaries by autonomously exploring and mapping underwater cave systems. Several other exploration projects are centered around UMVs. IBM teamed up with Promare, a nonprofit, to develop and deploy the 49 foot autonomous Mayflower.[49] IBM intended for the UMV Mayflower to retrace the path of the original Mayflower across the Atlantic, but technical problems cut short the first attempt.

All together, the landscape of UMV use is diverse: many different actors are using an array of UMV types to achieve their operational missions. The scientific and military communities are some of the farthest along in developing and deploying UMVs, though several wealthy private individuals are also pushing the boundaries through significant personal investments.

The technical challenges associated with UMVs are still significant, both in the development of UMV platforms that are able to withstand the harsh operational conditions of the ocean as well as in the creation of interfaces that allow humans to interact with and understand the many new UMVs on the ocean. These technical challenges are rapidly being overcome and in many cases, the major barrier to increased development and implementation is the regulatory uncertainty surrounding UMVs.

Part II: Current UMV Governance

UMVs are governed by a variety of different regimes, depending on their location, origin country and the type of the vehicle. This is a rapidly evolving area, with many countries and international

[49] Dalvin Brown, *An autonomous ship's first effort to cross the Atlantic shows the difficulty of the experiment,* WASH. POST (June 18, 2021), https://www.washingtonpost.com/technology/2021/06/18/mayflower-ibm-autonomous-ship/.

organizations currently drafting and adopting regulatory schemes to govern emerging types of marine robotics. These regulatory advancements must work in concert with existing maritime regulation, much of which is ancient, anachronistic, and unlikely to be updated. The constraints imposed by existing legal regimes and current proposals for regulating marine robots must bridge an ideal regulatory landscape with one that is feasible given existing laws. Many scholars and industry members agree that best approach is to create new laws governing marine robotics that can act in concert with existing regulation, as opposed to trying unsuccessfully to amend current international and national legislation.[50]

This section sets out the existing regulatory schemes governing robots in the marine environment, focusing on major US and international laws. Despite the myriad types of UMVs, nearly all of the discussion about UMV regulation is devoted to the regulation of large, commercial UMVs. This section discusses these proposals, noting where additional regulation is needed to effectively govern the full landscape of UMV use.

A. Public Law

Public laws at the national and international level are the primary mechanism for regulating vessels on the oceans, including UMVs. These laws in many cases codified centuries of custom in maritime operations. UMVs raise a variety of new issues that these regulations in many cases simply do not cover.

At the most basic level, several threshold questions about the status of UMVs determines whether maritime laws apply at all to these vessels. Public maritime law, both national and international, is written specifically to regulate vessels with the understanding that vessels would always be manned. The question of whether a UMV is a vessel is thus a fundamental one and one that is currently open to considerable debate.

The majority of academic discourse around marine robotics is devoted to the question of whether unmanned marine vessels (UMVs) should be considered vessels.[51] This threshold question is critical in determining whether applicable safety regulations and other maritime laws apply. It also determines whether UMVs are legally allowed to carry AIS, a GPS transponder that automatically transmits a vessel's information and location. AIS is used by other vessels to avoid collision, as well as by port authorities and law enforcement, but AIS units can only be placed on

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[50] Ringbom, *supra* note 4, at 11-12; DNV GL, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0026 ("To allow for autonomous unmanned ships it is better to formulate standards that apply to these ships separately, without amending current laws/standards…").

[51] *See e.g.* Craig H. Allen, *The Seabots are Coming Here: Should they be Treated as ' Vessels ' ?*, 65 J. NAVIG. 749–752 (2012); Allen, *supra* note 4; Ringbom, *supra* note 4; Commander Andrew H. Henderson, *Murky Waters: The Legal Status of Unmanned Undersea Vehicles*, 53 NAV. L. REV. 55 (2006); Rob McLaughlin, *Unmanned Naval Vehicles at Sea: USVz, UUVs, and the Adequacy of the Law*, 21 J.L. INF. SCI. 100 (2011); Daniel A.G. Vallejo, *Electric Currents: Programming Legal Status into Autonomous Unmanned Maritime Vehicles*, 47 CASE WEST. RESERVE J. INT. LAW 405 (2015).

vessels. Some UMV operators have determined that because their UMVs are not considered vessels they are not legally permitted to carry AIS units.[52]

The question of what is considered a vessel has come up throughout US history, most recently in *Lozman* where the Supreme Court determined that a houseboat incapable of its own propulsion was not considered a vessel. The US has codified a broad definition of what constitutes a vessel, including "every description of water craft, including non-displacement craft, WIG craft, and seaplanes, used or capable of being used as a means of transportation on water."[53] The Coast Guard has interpreted this expansively and developed a set of characteristics that constitute a vessel.[54]

Currently, by default many UMVs are functionally treated as vessels.[55] There are no alternative categories that could hold them under US or international law, with the possible exception of "hazards to navigation." Under US law, hazards to navigation are any objects that impede navigable waters. The Coast Guard or Army Corps is responsible for marking and removing these hazards.

NOAA itself acknowledges that some of its scientific UMVs are likely considered vessels by US definitions.[56] However, many are so small that applying vessel regulations to them makes little sense. Small, passively drifting scientific drones, for example, pose little to no risk of collision.

In some unclear cases, specific institutions have gone so far as to certify that certain UMVs are vessels. The Navy, for instance, has certified that several of it's UMVs are vessels, despite the fact that they are unable to comply with certain COLREGs requirements.[57]

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[52] SAILDRONE, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (Oct. 14, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0035.
[53] COLREGs, Rule 3.
[54] In finding that a paddleboard was a vessel, the Coast Guard articulated 5 factors to address:

1. Whether the vessel is practically capably of carrying persons or property,
2. Whether the operating range of the device is limited by the physical endurance of its operator
3. Whether the device poses a substantial hazard to navigation
4. Whether the normal objectives sought to be accomplished by the regulation of the device as a "vessel" are present, and
5. Whether the operator and/or cargo would no longer be safe in the water if the device became disabled.

NATIONAL ACADEMIES, *supra* note 2, at 163.
[55] For an argument that this functionalism threatens to undermine international law approaches to UMV regulation, *see* Allen, *supra* note 4, at 480 ("a functional approach is only appropriate when the treaty itself incorporated provisions for such flexibility (as do some IMO treaties listed in). Where, however, the treaty does not include such provisions we must look to more formal methods for treaty interpretation or amendment codified in the Vienna Convention on the Law of Treaties. Respect for the increasingly fragile global rules-based order requires nothing less.").
[56] NOAA, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (August 11, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0027.
[57] NATIONAL ACADEMIES, *supra* note 2, at 164.

On the other hand, other UMV operators argue that their UMVs are not vessels under current international or national regulations. Saildrone, for instance, notes that their small UMVs are not designed for transportation and therefore should not be considered vessels.[58]

Proposals to redefine what is a vessel may not fix this problem. Some definitions are so broad as to include anything "capable of traversing the sea."[59] On the other hand, the US definition that centers around the function of vessels to provide transportation for people or goods may exclude new types of UMVs, for instance scientific ones, that are doing neither, regardless of their size.[60]

Debate around this question in both the academic and commercial communities has been focused on historical understandings of what constitutes a vessel and how these questions will currently be interpreted under international law. The question that needs to be answered instead is functionally whether and which types of UMVs should be regulated as vessels. Does categorizing a UMV as a vessel help to promote the regulatory goals of our current international and national maritime regimes, to promote safety at sea and ensure environmental protection?

The ultimate answer to whether a UMV should be considered a vessel under current US and international laws will likely depend on the specific characteristics of the UMV in question. In this section, I will consider both laws applying to vessels and what laws apply to UMVs that are likely not considered vessels. Additionally, the second threshold question given the current regulatory landscape, is whether vessels are manned (either with some autonomous support or with humans completely out of the loop) or unmanned.[61] Hybrid systems that include crewmembers onboard vessels with any type of autonomous operation raise new questions around how current safety regulations and liability regimes will apply to them. Completely unmanned and autonomous vessels, on the other hand, raise a set of much more fundamental regulatory questions, including what is considered a vessel to begin with. It is this second set that I deal with here, focusing on the implications of the advent of Unmanned Marine Vehicles (UMVs).

<u>US Law</u>

The strongest legal regimes governing activities at sea are imposed by national governments. All vessels traveling on the world's oceans carry the flag of their home country and are subject to the laws of that flag state.[62] Flag states set laws that govern all aspects of vessel operation, from safety measures to liability regimes. Different flag states have dramatically different approaches to these standards, rendering marine vessel operation something of a patchwork. The most notorious example of differences in flag state regulation and enforcement is in the case of flags of convenience. Certain countries, generally those with relatively lax safety laws, low enforcement capability or favorable tax status, essentially sell their flag to interested vessels. Many private yachts, for instance, are registered in Bikini Atoll in the Marshall Islands, the site of

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[58] SAILDRONE, *supra* note 52.
[59] Allen, *supra* note 25, at 495.
[60] *Id.*
[61] SAVITZ, DAVENPORT, AND ZIEGLER, *supra* note 39, at 1-2.
[62] There are stateless vessels, these are highly discouraged and subject to universal jurisdiction of other states.

nuclear testing during the cold war that has left the island with radioactivity levels that make it unsafe to stay there for longer than 24 hours. Selling this flag is a significant revenue source for the Marshall Islands, while at the same time allowing yachts to be subject to the favorable regulations of the Marshall Islands.

Those UMVs that are considered vessels will need to be flagged under existing regimes, making them subject to the laws of their flag state. Flag choice may become an important decision for operators of marine robots. Today, certain countries already target specific types of vessel for registration: Vanuatu, for instance, has a flag of convenience that is heavily used specifically by passenger vessels that carry 20-30 guests. Savvy countries seeking to expand their ship registries may eventually wish to target UMVs and other types of marine robots by creating a favorable regulatory landscape for these vessels.

The US is slowly responding to the rise in marine robotics and much of the regulatory landscape is still being developed. Congress has recognized the importance of this area and initiated agency research on UMVs through the 2018 Commercial Engagement Through Ocean Technology Act which tasked NOAA with coordinating with the Navy to research, develop and use UMVs in their operations.[63]

While NOAA and the US Navy have been early movers on using UMVs, regulating UMVs will fall primarily to the US Coast Guard.[64] The Coast Guard began early stages of rulemaking on autonomous vessels with a Request for Information in August of 2020.[65] This was a broad call, asking for information from stakeholders on many questions related to the integration of new UMVs into the existing maritime regulatory system. This early RFI was devoted to the use of autonomous technologies for commercial purposes.[66]

The majority of comments in response to the USCG's RFI focus heavily on how UMVs will interact with existing maritime safety regulations. These safety regulations are primarily codified as part of the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) and Inland Navigation Rules. Industry and academic commenters believe that these regulations may need to be significantly modified to accommodate autonomous vessels. COLREGs in many places are based around actions required of crewmembers on board vessels. For instance regulations require a lookout onboard all vessels. This lookout is responsible not only for ensuring that the vessel is traveling safely and communicating via radio with others, but also to be available in the event of an oil spill.[67] Determining whether a UMV meets this lookout requirement if there is not a human onboard, either through technological sensors acting as a

[63] 33 USC Chap. 54.
[64] Other agencies, including EPA, Department of Commerce, and Department of Transportation also govern smaller aspects of marine robotic operation.
[65] US Coast Guard, *Request for Information: Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System* (Aug. 11, 2020).
[66] A distinction that other federal agencies were quick to jump on, wanting to make sure that any initial Coast Guard rulemaking did not apply to government actions. NOAA, *supra* note 56.
[67] 33 CFR § 155.5030.

human equivalent or through remote monitoring by humans onshore, will be critical in understanding how COLREGs requirements apply to UMVs. Existing case law can help to provide some clarity on how various terms have been interpreted in the past.[68]

Some technology developers argue that compliance with COLREGs is possible through programming autonomous vessels.[69] The US Navy piloted a Ghost Fleet vessel that was able to safely cross the Atlantic while complying with COLREGs requirements.[70] While this may be possible, ultimately COLREGs likely will need to be changed and updated in many different areas to accommodate unmanned vessels.[71] Some worry that adjusting COLREGs safety requirements to accommodate unmanned vessels will have a spillover effect by reducing crew on manned vessels, lowering safety standards across the board.[72]

COLREGs are further enhanced in busy port areas by Vessel Traffic Systems. UMVs must be able to integrate into existing VTS rules and interact effectively with non-autonomous vessels as well as other UMVs. Realistically, it may be some time before vessels are able to be completely unmanned in these areas due to the existing complexity of vessel operation.[73] This includes not only a high volume of other vessel traffic but huge heterogeneity in the types of vessels operating, from large cargo ships to jet skis and human swimmers.

Functionally, determining how UMVs can operate in compliance with existing regulations is usually done on a case-by-case basis, requiring technology developers to meet with a cross-section of government agencies and other stakeholders.[74] This approach makes sense right now, but will not be sustainable in the future with the increase in numbers of these types of vessels and a greater heterogeneity of operators.

Beyond core safety regulations, the US has several other regulations that place light limits on what vessels can do on the ocean. In general, certain types of extractive and commercial activities must be permitted, for instance fishing, oil drilling or mining. Activities that may negatively impact the environment, either by harming marine mammals or discharging pollution also require permits and environmental impact assessments. These regulations may apply to UMVs engaging in specific types of marine activities but are unlikely to apply to the majority of UMVs operating in US waters.

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[68] NATIONAL ACADEMIES, *supra* note 2, at 158-161 (2020).
[69] *Id.* at 136.
[70] https://news.usni.org/2020/06/23/program-office-maturing-usvs-uuvs-with-help-from-industry-international-partners
[71] For a full list of areas where current COLREGs may conflict with autonomous vessel operation, *see* Craig H. Allen, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (August 24, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0004.
[72] *Id.*
[73] *See* Marine Exchange of Southern California, *supra* note 24 (discussing the complexity of vessel activity in the waters around Los Angeles and the Port of LA).
[74] *See id.* (describing the measures taken by Boeing and Space-X to develop protocols for using their UMVs, including meeting with Coast Guard, Air Force, pilots, port officials and vessel traffic service).

International law

The primary international law governing activities on the ocean is the United Nations Convention on the Law of the Sea (UNCLOS). Additional International Maritime Organization (IMO) treaties and topic specific regulation fill in the framework created by UNCLOS to create the international maritime law system that we have today. Ensuring that UMVs are consistent with these laws, most of which were developed long before anyone even considered autonomous ships as a possibility, will require significant regulatory changes.

Like COLREGs, the Law of the Sea was drafted with specific language about the requirements for human crew. For instance, Article 94 of UNCLOS requires that flag states ensure "that each ship is in the charge of a master and officers who possess appropriate qualifications."[75] This is a major impediment to the adoption of autonomous, unmanned vessels. Academics and others are considering several workarounds so that UMVs can still meet these requirements, for instance by having land-based command centers with qualified masters "overseeing" the operations of UMVs.

The IMO in 2017 began a scoping process specifically to look at regulation of Maritime Autonomous Surface Ships (MASS). This scoping is focused on the advent specifically of large, autonomous ships used for carrying cargo. IMO scoping is still in early stages, with no intention of generating new international rules likely until the late 2030s. There is already debate about the effectiveness of the IMO process, for instance, the lack of clarity in the 4 different categories of autonomy created by IMO may cause regulatory confusion.[76] Others that the IMO's proposed autonomous vessel regulation may be ineffective on a broader level.[77]

The IMO's current process is to some extent informed by earlier, largely unsuccessful, moves toward automation. A push for One Man Bridge Operations (OMBO), or a reduction in the number of crew required to steer a vessel, in the 1980s led to proposed amendments to COLREGs but was ultimately unsuccessful due to concerns about safety and fragmented support from coastal states.[78]

Current international law also dictates where UMVs can operate. Under these provisions of UNCLOS, the purpose of UMV operation is pivotal. Certain activities, peaceful transit for instance, are allowed virtually everywhere throughout the ocean, while others, such as resource exploitation, are heavily governed by national law (when within 200 miles of a coastal nation's shore) or international organizations (when fishing in the high seas for instance).

An already popular approach is to claim that UMVs are being used for scientific research. Under UNCLOS, the freedom of scientific research is protected. On the high seas, marine scientific

[75] UNCLOS, art. 94.
[76] Ringbom, *supra* note 4, at 9.
[77] Craig H. Allen, *supra* note 72.
[78] *See* id; Henrik Ringbom, *Regulating autonomous ships—concepts, challenges and precedents*, 50 OCEAN DEV. INT. LAW 1, 11 (2019).

research is effectively unrestricted. Within coastal waters researchers must gain the consent of the coastal state, but coastal states may not withhold this consent if it is for peaceful purposes. While some have made the distinction between data collection for research purposes and for exploration purposes, in practice it may be difficult to determine when UMVs are actually engaging in research or in some other endeavor.[79]

IMO scoping is also limited to how autonomous ships may conflict with existing IMO conventions.[80] While an understandable focus and one that is reflected by the US Coast Guard's approach to regulating UMVs also, this focus inherently limits what IMO can accomplish. Current regulations will in some ways conflict with autonomous vessel operation, but the more pressing issue is whether current regulations will adequately regulate autonomous vessels.
The IMO is not asking this question. IMO conventions, all of which were drafted decades ago before autonomous shipping was even contemplated as an outlandish possibility, in many ways simply do not effectively address the questions posed by autonomous vessels. New regulatory regimes will be needed to fully respond to the challenges UMVs create.

For instance, current maritime law has little to say about underwater operations.[81] While surface operations are regulated under both national and international regimes, subsurface operations have few regulatory limits. Historically, submarines were limited and primarily operated by militaries. This landscape is changing, with the advent of many new actors using UUVs. While some view the lack of regulation in this area positively, with no impediments to UUV operation or experimentation, increasingly widespread UUV operation is not without risks.[82] It will be important to create regulatory regimes for marine robots that address not just surface, but also subsurface vessel operations.

In the interim of full IMO regulation, alternate mechanisms aside from the formal adoption of new regulations or revisions to existing Conventions could help to informally regulate autonomous vessels. Circulars agreed upon by IMO members that clarify some of the important legal questions around UMV operation could provide interim guidance for the development of this field.[83]

B. Private governance

Liability is an important component of recovering from accidents at sea. The principles of these private regimes are well-established when it comes to manned vessels. Apportioning liability when UMVs are involved is likely to initially be more difficult due to complicated questions around how causation and fault are determined. No UMVs have yet been a part of a major collision at sea, but it is only a matter of time before this happens.[84] Some have suggested that

[79] Bork, *supra* note 15.
[80] *Id,* at 21.
[81] NATIONAL ACADEMIES, *supra* note 2, at 141.
[82] *Id.*
[83] Ringbom, *supra* note 4, at 20.
[84] SAVITZ, DAVENPORT, AND ZIEGLER, *supra* note 39, at 5.

owners and operators of UMVs should be held to strict liability standards for any damages they cause.[85]

Interestingly, the largest concerns for operators and policy makers arise around the implementation of fully autonomous ships. Many see remote operation or some degree of human oversight as important, risk-reducing intermediate steps.[86] However, remote control of vessels raises its own questions around liability. For instance, in collision avoidance situations, the communication delay between a vessel and its remote operators is likely to be significant enough to seriously impede the effectiveness of remote control.[87] This is a foreseeable issue and may raise potential tort liability for these types of vessels.

Outside of the formal governance mechanisms created by national and international regulatory frameworks, private governance and other informal mechanisms may be the early drivers of how UMVs functionally are governed. The private sector is already developing its own methods of informally governing marine robotics in the absence of formal regulation from governments. The American Bureau of Shipping, for example, has developed guidelines to shape how various ship-based systems can be developed to be compatible with autonomous operation and new hybrid autonomous support systems.[88]

Classification agencies play an important role in regulating marine industries, particularly when it comes to larger shipping and commercial vessels. Classification societies are responsible for developing standards and certifying that vessels meet these standards.Major classification societies have already created their own guidelines on autonomous vessels.[89] While these guidelines remain in many ways vague, they are early attempts to identify key issues related to UMVs and provide consistent guidance to other maritime sectors.

Similar to classification societies, insurance companies have also been relatively early movers in providing guidance on autonomous vessels. Lloyd's Register, for instance, both a classification society and the single largest marine insurance company, issued guidance on autonomous vessels in 2016.[90] This guidance provides a process for identifying, mitigating and classifying the risks associated with UMV operation. Other insurance companies have already thought through the regulation of UMVs in depth as well.[91]

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[85] Craig H. Allen, *supra* note 72.
[86] *See e.g.* American Bureau of Shipping, *supra* note 28 (advocating for the use of Remote Control and Operations Centers for autonomous vessels).
[87] Ringbom, *supra* note 4, at 16.
[88] American Bureau of Shipping, *supra* note 28.
[89] *See e.g.* DNV GL, *Autonomous and Remotely Operated Ships Class Guideline* (2018), https://rules.dnv.com/docs/pdf/DNV/cg/2018-09/dnvgl-cg-0264.pdf.
[90] LLOYD'S REGISTER, *Cyber-Enabled Ships: ShipRight Procedure- Autonomous Ships* (2016), http://info.lr.org/l/12702/2016-07-07/32rrbk.
[91] Gard AS P&I Club, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 1, 19 (October 14, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0028.

Anecdotally, marine companies are concerned that switching to more autonomous vessel technologies may raise insurance prices at least temporarily.[92] However, reduced personal injury claims from injured crew combined with better storm avoidance may decrease costs.[93]

These private governance avenues will be critical in determining how UMVs are deployed and governed in the year before formal national and international regulations are issued. This is a particularly effective mechanism when it comes to addressing safety and liability issues, both areas that insurance companies and classification societies are heavily focused on. Other larger questions, like whether UMVs should be classified as vessels or what constitutional or regulatory limits on their operation may exist, are less likely to be addressed through private governance avenues.

C. Failures in UMV governance

Approaches to UMV regulation have been slow and fragmented. The delay in adoption of formal governance regimes disincentives commercial investment and government adoption during this time of uncertainty. IMO, for instance, does not anticipate having concrete rules governing autonomous ships until at least 2030.[94] Some companies cite regulatory uncertainty specifically as the largest barrier to implementation of autonomous systems, not technical challenges or other logistical concerns.[95] There is already a significant gap between the types of automation occurring on ships on a smaller scale, whether monitoring engine rooms or steering the boat with autopilot systems, and regulatory policy.[96] The past approach has been to make case by case determinations as these systems emerge, a policy that will not continue to be effective with continued increases in these types of technological advancements.

The slow pace of developing governance mechanisms for UMVs also potentially allows illegal actors to use emerging robotic technologies to their advantage: while government enforcement agencies are still debating how to operate UMVs legally, drug traffickers may begin using these same technologies.[97]

Some of this pace is dictated by an attitude that autonomous operation of ships is not technologically or politically feasible in the near term.[98] This is a myopic approach. Current trials

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[92] OneSea, *supra* note 21.
[93] Gard AS P&I Club, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 14, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0028.
[94] Craig Eason, *No Rules on Autonomous Ships for Another 10 Years- At Least,* FATHOM WORLD (June 21, 2020), https://fathom.world/no-rules-on-autonomous-ships-for-another-10-years-at-least/.
[95] American Waterways Operators, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0024.
[96] *Id.*
[97] SAVITZ, DAVENPORT, AND ZIEGLER, *supra* note 39, at 3.
[98] Ringbom, *supra* note 4, at 14 ("The prospect of a fully developed autonomy, in which a ship undertakes an entire voyage totally without human supervision or involvement, is hardly realistic in the short term."); Craig H. Allen, *Determining the legal status of unmanned maritime vehicles: Formalism vs functionalism*, 49 J. MARIT. LAW COMMER.

of both small and large, commercially viable UMVs in recent years has shown that UMV operation is technologically feasible with capabilities improving almost exponentially. Regulation must move faster to be able to effectively handle the realities of marine robotics.

More legitimate reasons for the slow pace of regulation stem from caution: the IMO itself has noted that is acting cautiously to ensure that the regulations adopted are effective and appropriate.[99] Other industry actors agree, noting that caution is warranted given the potential costs of automation on safety and marine workforce.[100]

The pace of change is also limited by regulatory systems themselves. Amending applicable instruments or creating new standards and then waiting for actors to come into compliance with them will take a significant amount of time. This in some ways emphasizes the need for more rapid regulatory response. If it takes 10 years from when a standard is promulgated to when changes begin to be seen on vessels, many of these changes should be made sooner rather than later to avoid regulatory gaps.[101]

Not only has the approach to regulating marine robots been slow, it is also fragmented. In lieu of IMO regulation, domestic laws and policies around UMV use will dictate the landscape. Functionally, this means a variety of different outcomes and approaches.[102]

This is true not only between countries, but also within countries. NOAA's current plan to develop their own Best Management Practices in lieu of guidance from the Coast Guard is early evidence of this fragmentation. The longer regulation takes to be enacted, the more individual entities will develop their own regulatory mechanisms that may or may not be consistent with what is ultimately enacted by the Coast Guard or the IMO. While federal agencies have made statements about their wish to coordinate, and in some cases Congress has required this coordination, it is not clear that these activities are happening rapidly enough to prevent divergent regulatory systems from being created.

477, 479 (2018) ("A.P. Moeller-Maersk Chief Executive Officer Soren Skou expressed his company's assessment that "[e]ven if the technology advances, I don't expect that we will be allowed to sail around with 400-meter long containers ships weighing 200,000 tonnes without any human beings on board.").

[99] Maritime Safety Committee, MSC 99/5/1, Feb. 22, 2018.

[100] Transportation Trades Division AFL-CIO, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0036

[101] *See* Radio Technical Commission for Maritime Services, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 12, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0017 (noting that "it may take a decade or more from the time a change to an ITU standard is initiated, to the time consequential changes to relevant IEC standards are made, and then until compliant equipment becomes available on ships…").

[102] *See e.g.* Gard AS P&I Club, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 14, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0028 (discussing different national approaches to determining COLREG compliance).

Temporary fragmented regulation is a problem both for agencies and the commercial sector supplying them. If commercial actors develop technologies that meet certain agency standards, these may eventually be grandfathered in if regulatory regimes change dramatically in the future.

Fragmented regulation also prevents companies from implementing needed security measures. Cyber security is a critical issue to address for UMVs. One of the most important aspects of UMVs is they move oversight of vessels from directly on the ship to an operations center on land.[103] Even those UMVs that are operating completely autonomously are likely to have some degree of human oversight from operations hubs. Transmitting information securely between UMVs and shore then becomes a critical concern.

Additionally, UMVs can be more easily captured than manned vessels. Many small UMVs can be easily picked up, either intentionally or unintentionally by other vessels. This has happened already, with different fishermen capturing both presumed US Navy and Chinese UMVs.[104] For more sensitive missions, the ease of capture of these small devices raises important security concerns about the data available on the devices.

Larger UMVs, those ultimately replacing manned cargo ships, are likely to be attractive targets for pirates. Without crew to defend them, it may be much easier to capture large autonomous ships. Industry leaders are seriously considering both the cybersecurity and security issues raised by the advent of large autonomous ships, though relatively little attention has been paid to the smaller classes of UMVs.

Commercial uncertainty and concerns about security risks are a critical impediment to success going forward. Commercial technology innovation depends on predictable markets to sell their products into. The potential customer pool for marine robotic technologies is inherently limited, different national regulatory regimes may limit this pool even further.

Proposals for UMV regulation also fail to look holistically at the landscape of UMV use and address all potential legal challenges that they raise. The focus on updating safety regulations to accommodate UMVs is important, but it is only a small fraction of the legal issues that must be addressed to create effective UMV regulation.

Part III: New principles for regulating UMVs

Several areas of UMV regulation are already being well addressed, as discussed above. However, major gaps exist. The current regulatory landscape raises fundamental questions about how UMVs can and should be regulated. Either under existing frameworks or through new regulatory

[103] Ringbom, *supra* note 4, at 9.
[104] Rachel Zhang and Lauren Chou, *Chinese fishermen find drone ship 'used for spying by a foreign country'*, S. CHINA MORNING POST (Apr. 16, 2021), https://www.scmp.com/news/china/military/article/3129897/chinese-fishermen-find-drone-ship-used-spying-foreign-country.

initiatives, many of the legal aspects of UMV deployment must be more effectively addressed going forward.

UMVs are already active in the oceans and need better governance now, not decades in the future. The landscape of UMV use is varied and regulation must be able to accommodate this. It also should recognize that in the next decade, the focus for UMVs will be more on development and likely less on deployment, with several countries establishing specific areas solely for testing autonomous vessels.[105] Regulatory regimes must consider how to regulate UMV testing and experimentation as well as final implementation.[106]

This section provides an overview of the major legal challenges raised by UMVs outside of the core proposals to update COLREGs and other marine traffic schemes, identifying key governance gaps that should be addressed and proposing principles for regulation of UMVs moving forward. These proposals are tailored specifically for US regulation, though the fundamental principles apply equally to other national and international proposals.

1. *Regulation should be based on type of UMV*

The majority of UMVs in use today are relatively small, non-commercial vehicles that are very different than the autonomous surface ships that are taking up the majority of regulatory attention. It is critical that regulatory bodies not overlook regulation of early UMVs just because they are relatively small or low-risk compared to large, complex MASS. It will likely be decades before fully autonomous cargo ships are in use, but a wide variety of other types of UMVs are already in routine use and growing exponentially. Regulators must recognize these UMVs when drafting and creating legislation.

International and national maritime laws apply to all vessels, regardless of their operator. In certain cases, these regulations can either be relaxed or tightened for specific types of actors, however the same basic principles apply across the board.[107] In looking at regulation of UMVs, putting UMVs into the broad vessel category in some cases would help achieve regulatory goals and in others would likely hinder effective outcomes. UMV regulation should take these differences into account, delineating between different types of UMVs and not attempting to regulate the diverse landscape of UMVs as one monolith.

Scientific gliders and floats, for instance, are fundamentally different in their operation and consequences than large autonomous surface ships. It is unclear whether small, passively

[105] Norway's designated test fjord is by far the most charismatic of these sites, https://www.kongsberg.com/maritime/about-us/news-and-media/our-stories/test-site-for-autonomous-vessels/.
[106] NATIONAL ACADEMIES, *supra* note 2, at 4.
[107] For instance, militaries routinely exempt themselves from COLREGs requirements, *see* Craig H. Allen, *Determining the legal status of unmanned maritime vehicles: Formalism vs functionalism*, 49 J. MARIT. LAW COMMER. 477, 510 (2018) (noting the Secretary of the Navy's has exemptioned several UMVs from meeting COLREGs), while nations often impose stricter safety and inspection requirements on commercial vessels than recreational vessels.

powered scientific floats would be considered vessels under current international definitions.[108] Most academics argue that these probably should not be considered vessels. Unfortunately, the corollary result of not considering small, passively powered UMVs vessels is that they are effectively unregulated. New categories need to be created to regulate the full landscape of UMVs, as applying the full international and national regulatory requirements of ships to them is unnecessary and inefficient.

The regulation of aerial drones provides some insight here. It is insight that many in the maritime world are already familiar with, given that many marine entities were early adopters of Unmanned Aerial Systems (UAS).[109] Many of the issues facing UMVs have already been addressed with aerial systems, from debate over whether the FAA's aircraft definition includes small drones to complex technical safety discussions on how best to integrate new UAVs into existing airspace management frameworks. These provide an important starting point for discussions around UMV regulation.

Congress led early UAS regulation with the 2012 FAA Modernization and Reform Act.[110] This split aerial drones into three major categories: public, civil and recreational. FAA then further split drone regulation up by size, going through a rulemaking specifically for small UAS (under 55 pounds). The small UAS rule provides an interesting template for small UMVs. The small UAS rule applies to both public and civil drones, but provides an additional carve out that exempts purely recreational use from the majority of the requirements of the rule.[111] Small UAS operation is subject to certain limitations not only in the size of the drone, but also the speeds, altitude and times at which they can be operated. Operators must obtain a pilot certification and register any drones they use with the FAA. Recreational users are exempt from pilot certification and other requirements of the small UAS rule if they comply with stricter operational requirements, including using drones only within line of sight.[112]

This model, regulating by user type as well as size of the vehicle, is one that the Coast Guard should draw upon for UMV regulation. UMVs should be categorized based on relative risk posed based on the size, speed and function of the vessels.[113] This conforms with existing regulation that imposes stricter requirements on certain types of vessels.

Some argue that we should draw the line by considering whether UMVs are "capable of navigation" or actively propelled.[114] Others add to this the size and function of the UMVs, all of

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[108] Bork, *supra* note 15, at 308 (arguing that despite the uncertainty, floats and gliders likely should not be considered ships under international law).

[109] *See e.g.* NATIONAL ACADEMIES, *supra* note 2, at 45-52 (describing the Coast Guard's use of aerial drones).

[110] FAA Modernization and Reform Act of 2012 (FAA Reform Act), Pub. L. 112-95, § 331-336, 126 Stat. 72, (2012).

[111] 14 CFR Part 107.

[112] 49 USC 44809.

[113] SAILDRONE, *supra* note 52.

[114] *Id.*

which serve to dictate the potential consequences of a collision.[115] UMVs over a certain size and capable of "transportation" are more likely to be considered vessels and fall under existing legal frameworks. These UMVs will need additional regulation beyond what is in place, but it is also essential that smaller UMVs that would not otherwise be considered vessels have some regulatory frameworks in place. Size categories then might be based around the interpretation of what is considered a vessel: UMVs that are large enough to be considered vessels are subject to the full weight of existing international requirements in addition to UMV specific regulation. UMVs that are too small to be considered vessels and without major propulsion could be regulated akin to small UAS: subject to some training and operational limitations, but not subject to the full requirements of large UMVs like MASS.

Certain extremely low risk, recreational UMVs that are unlikely to fall under the UNCLOS or Coast Guard definition of a vessel should be subject to similar carve outs to those created for recreational aerial drone use. Small, tethered recreational ROVs for instance, pose very little risk to other people or vessels. The regulatory history of drones reveals the importance of not underestimating the impacts of relatively small commercially available units. These were the first types of drones widely available and the missteps, and subsequent outcry, caused in early days by these has characterized the entire regulatory approach to aerial drones going forward. Creating avenues to ensure that small recreational UMV users comply with basic marine safety principles without having to meet onerous international standards is likely the best approach.

Creating clear legal distinctions about what characteristics UMVs must have to be considered vessel or be placed in other regulatory categories is essential to ensure commercial predictability and spur continued investment in this type of technological development.[116] The desire for certainty in this sphere has led other agencies, primarily NOAA, to begin the process of developing their own Best Management Practices to oversee autonomous vessel deployment.[117] This reflects an already fragmented approach to autonomous system deployment more broadly.[118] While an understandable response to the lag between the rapid adoption of these new technologies and a regulatory scheme for them to operate in, this is not the ideal outcome. The Coast Guard should create a unified approach to UMV regulation that applies across sectors and agencies.

This consistency is essential not only for investment and innovation in this area, but to ensure that marine robotic technologies are employed to their full potential. NOAA, for instance, has had an ad hoc approach to UMV deployment that has been relatively successful, but they recognize the potential downsides of that approach so have recently centralized operations to create a unified approach to UMVs.[119]

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[115] *Id.*
[116] NOAA, *supra* note 56.
[117] *Id.*
[118] *See* NATIONAL ACADEMIES, *supra* note 2, at 70-80 (2020) (discussing different agencies varying approaches to autonomous system deployment and governance).
[119] NATIONAL ACADEMIES, *supra* note 2, at 80.

2. Regulation should be performance/goal-based

The Coast Guard believes that they "must promote a shift from a rules based regulatory structure in the maritime environment to a risk and principles-based regulatory structure to keep pace with emerging issues and technology advancements, such as electronic and autonomous systems."[120]

Similarly, the IMO has recently transitioned to using more Goal Based Standards as regulatory mechanisms.[121] Like the Coast Guard approach, IMO's standards focus on setting performance goals and allowing the details of how these goals are met up to the regulated entities. This increases flexibility and opportunity for innovation, while also ensuring that baseline standards are met. Industry players are also supportive of the shift to goal-based regulation.[122]

Establishing goal-based regulation allows for flexibility and may be able to draw on the important role of classification societies in maritime vessel development. Classification societies can create more technical standards for how government regulatory goals can be achieved.[123]The IMO's International Safety Management Code is a potential example of regulatory goals framed at the right level of specificity to allow flexibility and innovation in the face of new developments.[124]

Others are advocating for approaches that focus on developing standards that address technology characteristics and not specific technologies themselves throughout the landscape of emerging technology regulation. Some have argued that the Coast Guard and other governing bodies should outsource the development of these standards to third parties to try to improve the current slow pace of regulation.[125]

3. Regulation should address environmental concerns

UMVs raise new environmental questions. Marine robots by their nature will break down at sea. Larger MASS will likely be worth repairing and recovering but smaller vessels are currently left to drift and eventually break up. This is cheaper and more efficient for operators than expending the resources needed to recover UMVs at sea. The Coast Guard, for instance, is prioritizing UMVs

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[120] U.S. COAST GUARD, *Maritime Commerce Strategic Outlook* 1, 29 (2018).
[121] Ringbom, *supra* note 4, at 24.
[122] *See e.g.* DNV GL, *supra* note 50; Gard AS P&I Club, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 14, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0028 ("Coast Guard should consider that national regulation of autonomous ships should be in the form of goal-based framework regulation accomplished through the use of industry-specific technical standards and codes of conduct for autonomous ships, some of which are already available as guideposts,3 rather than through prescriptive regulation.").
[123] *Id.*
[124] *Id.*
[125] American Waterways Operators, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0024.

that are affordable enough that they can be sent on one-way missions and never retrieved.[126] This may increase operational efficiency for the Coast Guard, but it raises important environmental questions about abandoning UMSs at sea.

Likewise, many of the scientific floats deployed in the world's oceans are not designed to return to shore. Instead, once they reach the end of their lifespans they continue drifting until they either wash up on shore or sink. Addressing end of life issues is essential for UMV regulation going forward.

UNCLOS and MARPOL have provisions prohibiting marine dumping. In particular, dumping plastics is illegal throughout the oceans.[127] Arguably deploying UMVs, all of which have significant plastic components, with the intent that these UMVs never be retrieved is already in violation of MARPOL's provisions. It is essential that these measures be more thoroughly considered when it comes to UMV disposal. Regulators should weigh the importance of preventing marine litter with the reality that many small UMVs may malfunction and make retrieval infeasible.

Salvors also play an important role in decreasing the likelihood of vessels left to drift at sea by helping to save boats that have been in major accidents in return for a portion of the vessel's value if and when their efforts are successful. The Coast Guard should clarify whether existing salvage regulations will also apply to UMVs.[128]

Some agencies worry that the rise of automation and UMV use generally will lead to increased maritime accidents, oil spills, and other types of environmental harm.[129] Some early work has been done to draw on lessons from human failures in aviation to better inform marine uptake of autonomous technologies.[130] Policymakers and technology developers must build upon these efforts to ensure that technology deployment is as safe as possible. On the other hand, oil spill response is potentially a prime use case for UMVs. The environmental impacts of marine robots have not been effectively evaluated. Future regulation must consider how UMVs fit into existing environmental and maritime dumping regulation.

4. Regulations should consider new actors and uses of UMVs

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[126] NATIONAL ACADEMIES, *supra* note 2, at 36.
[127] MARPOL, Annex V.
[128] Gard AS P&I Club, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 14, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0028.
[129] Washington State Department of Ecology Spills Prevention, Preparedness, and Response Program, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0037 ("With even less people to perform maintenance, respond to incidents, and provide assistance to maintaining effective watches, the risks of accidents like oil spills increases.").
[130] *Id.*

In general, the focus of discussion around UMV regulation has been heavily focused on commercial vessels transitioning their existing operations to use more autonomous technologies.[131] This leaves out three important categories of UMV operators: government entities, scientists, and other private individuals. It also ignores new classes of UMVs that are undertaking new projects that were infeasible for manned ships. New forms of resource extraction and other types of operation are possible with the advent of UMVs and many of these are essentially ungoverned.

The majority of discussion around these new uses is in relation to deep-sea mining. Deep sea mining is only practically and economically feasible with UMVs. UMVs are catalyzing new capabilities for resource extraction. However, the drafters of UNCLOS did recognize the possibility that mining on the seabed could move from shallow coastal waters to deeper, international waters. It created a rudimentary regime to govern allocation of seabed resources in areas beyond national jurisdiction.

This framework was created when UNCLOS was drafted in the 1980s and was not seriously debated until the last couple of years. Now, Nauru has demanded acceleration of this process by requiring that the International Seabed Authority issue final rules to govern deep sea mining.

<u>Law enforcement</u>

Law enforcement, primarily the US Coast Guard and other nation's equivalents, are already turning to the promise of UMVs in many of their operations. It is critical that meaningful constitutional limits are in place to protect individual rights at sea.Conversation around aerial drones is heavily centered around what limits the 4th Amendment places on their use. While the ocean presents a very different case than the airspace above people's homes, the 4th Amendment still applies. Many argue that 4th Amendment limits are already unconstitutionally weak on the ocean. Adding UMVs to this mix has the potential to exacerbate this. UMVs are already being used for military surveillance and law enforcement use is increasing as the Coast Guard and others turn to UMVs. Regulation of UMVs should help to define clearer lines that protect 4th Amendment rights for those at sea. Surveillance on the private areas of a ship

<u>Private actors</u>

In other areas, there is not even a rudimentary framework for governing the new types of operations made possible by UMVs. In the environment, for instance, there has been a dramatic rise in private sector actors developing robotic technologies aimed to actively intervene in marine ecosystems. From projects to remove plastics form the ocean to ocean iron fertilization efforts intended to sequester carbon dioxide, non-governmental actors are using UMVs to reshape the landscape of environmental intervention.[132] These new technology projects are seen by many as a critical hope in human efforts to mitigate increasing environmental degradation.[133] The

[131] As evidenced by the IMO's regulatory scoping focused on large, autonomous commercial surface vessels, and the US Coast Guard's RFI that deals only with commercial vessels.

[132] Raphael Sagarin et al., *Iron Fertilization in the Ocean for Climate Mitigation: Legal, Economic, and Environmental Challenges* 1 (2007).

[133] OECD, RETHINKING INNOVATION FOR A SUSTAINABLE OCEAN ECONOMY (2019).

potential economic and ecosystem benefits of these interventions are high, ranging from combatting climate change to supplying needed protein for a growing global population.[134] The potential costs, however, may be even higher. Historical human attempts to mitigate damage and improve the environment have often instead caused irreparable harm.

Ocean ecosystems are facing unprecedented threats. Climate change is threatening over 75% of the world's reefs with imminent bleaching.[135] Illegal, Unregulated, and Unreported fishing robs nations of an estimated $23 billion annually, undermining fisheries management and threatening global food supply.[136] In April 2019, an expedition to the bottom of the Mariana Trench, nearly 6 miles beneath the ocean's surface, discovered microplastics in the water.

The extent of these impacts has galvanized global support and catalyzed a new wave of ocean technologies that seek to mitigate environmental damage and restore, or improve, ocean conditions. Nowhere has enthusiasm been greater than around proposed solutions to ocean plastic pollution. The Ocean Cleanup, for instance, launched a giant boom-system in 2018 to great fanfare with the goal of sweeping up plastics in the ocean. Boyan Slat, the founder, was hailed as a boy genius and gave talks about his design to world leaders at Davos and TED. The Ocean Cleanup successfully raised millions of dollars, including sponsorship from some of the most prominent maritime companies in the world like Maersk.

Before The Ocean Cleanup was deployed, large parts of the scientific community voiced concerns about the viability of the technology as well as its impact on fragile marine ecosystems. These concerns were not addressed, nor was there any regulatory oversight or requirement that TOC complete an environmental impact analysis. The deployment of The Ocean Cleanup was an important indicator of what could be to come for the environment and highlighted the current reality of ocean governance: gaps in regulation easily allow large-scale private enterprises intent on permanently altering environmental conditions to move forward with little to no scientific or legal oversight. Decreasing costs and increasing capabilities of UMVs are enabling these projects.

The Ocean Cleanup is a relatively mild scenario, with the consequences limited to small scale introduction of more plastics into the ocean (when the prototype broke) and local disruption of ecosystems (assuming the system is never deployed globally). Other technology interventions may not be so mild, from geoengineering options that aim to alter atmospheric conditions to mitigate climate change to genetic recovery projects relying on UMVs to collect and potentially move threatened species to new ecosystems. Even small projects, like The Ocean Cleanup, can have irreversible negative impacts at a significant scale when viewed cumulatively.

These projects currently operate in a grey area under most US and international laws and consequently have very little regulatory oversight. The Ocean Cleanup, for instance, was self-

[134] *See e.g.* U. Rashid Sumaila, Christophe Bellmann & Alice Tipping, *Fishing for the future: An overview of challenges and opportunities*, 69 MAR. POLICY 173 (2016); Albert C Lin, *The missing pieces of geoengineering research governance*, 100 MINN. LAW REV. 2509 (2016).
[135] LAURETTA BURKE ET AL., REEFS AT RISK REVISITED (2011).
[136] DANA D. MILLER & U. RASHID SUMAILA, IUU FISHING AND IMPACT ON THE SEAFOOD INDUSTRY (2016).

labelled a research mission and operated under the Law of the Sea's Freedom of Scientific Research. A close reading of UNCLOS shows that this is a misinterpretation of what is considered scientific research. Similar issues are raised by other types of marine technology projects.

Current US marine and environmental regulations are ill-equipped to effectively govern these emerging technological solutions. Major federal command and control laws are unable to meet the new types of challenges posed by technology interventions that are not polluting or harming ecosystems, but are actively seeking to improve them. Wider reaching environmental laws, like NEPA, that require environmental impact analysis do not apply to purely private projects that need no federal permits or financing. National and international maritime laws only govern certain types of historical activities, from fishing to research. The result is that many of these new, large-scale technologies are operating in a governance gap and are effectively unregulated by current legal frameworks.

Private-sector robotic technology interventions are a major shift from historical models of ocean governance both in the parties that are driving these interventions and in the aims of these projects. Such large-scale interventions were once primarily the province of governments. While wealthy philanthropists and others have made significant contributions to land-based conservation efforts, historically private efforts to conserve marine ecosystems have been limited in scope. The cost, expertise, and motivation needed to make significant changes to ocean conditions precluded private actors from engaging in large-scale environmental alteration. While corporate action has been an important feature of ocean governance,[137] the rise of large-scale direct action by private parties to remediate and improve ocean conditions is relatively new.

The scope and goals of technology interventions in the ocean are also pushing into new territory for environmental management. The majority of federal environmental regulation has been based around conservation of existing ecosystems, for instance through pollution control or environmental species protection. Some environmental laws deal with remediation efforts, most notably CERCLA, but these are limited in scope. NEPA's procedural safeguards apply only to major federal actions. While this also includes private projects that require federal permits, many environmental technology projects operate in areas where no permits are needed and are thus outside of NEPA's reach. Large-scale efforts to restore or improve marine ecosystem conditions through the use of new technology tools are left free to operate with little to no regulatory oversight. The impacts of these projects, both individually and when viewed cumulatively, demand a more comprehensive governance approach.

UMV regulation should consider the many different ways that UMVs are being used, and attempt to fill regulatory gaps by creating mechanisms to hold UMV operators accountable for environmental and other damage that they may cause. UMV regulation should additionally impose light environmental impact assessment requirements for projects actively aiming to alter ocean ecosystems.

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[137] Michael P. Vandenbergh, *Private environmental governance*, 99 CORNELL LAW REV. 129–200 (2013).

5. UMV Regulation should draw on regulation of parallel robotic advancements

Policy makers should look outside of marine contexts to other areas of emerging technology that can provide key insights into what an effective regulatory landscape for UMVs should look like. Understanding human-machine interactions, for example, will be essential to developing UMV systems that are as safe and efficient as possible. Current evidence suggests that the relatively low levels of automation already present on vessels with human crew, for instance advanced autopilot systems, are confusing to mariners.[138] This confusion is already a major reason for vessel collisions, a trend that will only continue as automation onboard vessels becomes more advanced.[139]

Likewise, significant discussions are occurring in other fields about the future of work. In general, the cultural and workforce impacts of increased use of UMVs have been recognized but only at a cursory level. Union representatives, in particular, have criticized current regulatory efforts for their lack of attention to key questions around the effect of UMVs on the merchant mariners.[140] This attention is particularly important now, as UMV use is rising in the face of a rapidly declining merchant marine workforce. Despite protectionist laws designed to ensure the US retains a sufficiently trained merchant marine in the event of war, the US merchant marine is dwindling rapidly.[141]

The advent of autonomous ships will likely decrease the number of working merchant mariners. How much of a reduction is currently open to debate.[142] Moreover, the character of maritime jobs will change significantly, with support personnel on shore and potentially onboard larger ships as they transition to full automation.[143] At the same time, there will be an increase in jobs developing and overseeing UMVs.[144]

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[138] Felski & Zwolak, *supra* note 22.
[139] *Id.*
[140] Transportation Trades Division AFL-CIO, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0036 (arguing that the USCG's 2020 RFI was "structured and written in a way to generate comments that extol the values of automation and supposed cost savings while giving short shrift to critical questions of safety and impacts to the maritime workforce.").
[141] Transportation Trades Division AFL-CIO, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0036.
[142] *See* Craig H. Allen, *supra* note 72 ("some shrinkage in the number of seagoing billets will be lost. A few shoreside "operator" positions will open but, assuming such shoreside operators will control more than one vessel at a time and perhaps for longer "watches" than seafarers typically stand, the trade-off will be less than 1:1. In the area of unintended consequences, if regulatory manning and watchstanding requirements are relaxed to accommodate autonomous vessels, that may spill over and lead to further moves to reduce manning on manned vessels."); Joseph Bennington Castro, "Seafarers and Digital Disruption", Hamburg School of Business Administration, October 2018, https://www.ics-shipping.org/docs/default-source/resources/ics-study-on-seafarers-and-digitaldisruption.pdf?sfvrsn=3 ("even if as many as 3,000 autonomous or semi-autonomous ships are introduced by 2025, there will be no shortage of jobs for seafarers in the foreseeable future…").
[143] *See e.g.* GMATEK, *supra* note 23.
[144] *See e.g.* NATIONAL ACADEMIES, *supra* note 2, at 95 (discussing career paths in UMVs).

Increased UMV use may fundamentally alter the relationship between mariners and the ocean. Today's Coast Guard and other merchant mariners spend the majority of their time at sea. They become attuned to seafaring and marine conditions.[145] The level of knowledge gained through experience on the ocean is legally enshrined in COLREGs, several rules of which refer specifically to the "ordinary practice of seamen" as standards of conduct.

Shore based operators will have a very different understanding of ocean conditions. While many still argue the importance of UMV operators being trained in the same ways as mariners, there may still be a gap in how shore-based crew understand and interact with changing ocean conditions. Understanding and adapting to changing ocean conditions is essential to minimize damage to vessels, and something that autonomous programming may be relatively bad at compared to trained humans.[146]

The impacts of marine automation will likely also have impacts outside the marine industry. For instance, early pilots in Europe intend to replace larger ships with smaller, electric powered ones servicing smaller ports.[147] These ships will reduce the use of trucks on the road transporting goods between large port facilities and outlying areas.

Some other cultural norms of seafaring will also be at risk with the move to UMVs. For instance, one of the most fundamental duties of mariners is that of providing assistance to vessels distress.[148] Whether UMVs should be programmed to respond to distress calls, and if so how they can provide assistance will be just one of the important cultural questions around UMV implementation to answer.[149]

Conclusion

UMVs are dramatically expanding what humans can accomplish on the oceans. However, investment and development in the UMV sector is undermined by regulatory uncertainty. Thousands of UMVs are already in use around the world, operating in regulatory gray areas as operators await clarity from national and international regulatory bodies.

Comprehensive regulation of UMVs is needed, not just to ensure that navigation and safety goals are met, but that understand the diverse impacts that UMVs may have on the oceans.

[145] GMATEK, *supra* note 23.
[146] American Bureau of Shipping, *supra* note 28.
[147] Radio Technical Commission for Maritime Services, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 12, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0017.
[148] In some cases, this duty has been codified as a legal obligation.
[149] *See* Radio Technical Commission for Maritime Services, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System 85 FR 48548 (October 12, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0017 (discussing the communications issues raised with autonomous vessel response to distress calls).

Considering the full landscape of UMV uses and consequences highlights key areas where modifying existing regulations will likely not be enough to effectively govern UMV use. New regulatory frameworks, spearheaded by national governments in lieu of formal and timely action by the IMO, need to take into account new uses of UMVs and plan for environmental, workforce and surveillance impacts. Private governance mechanisms, through ship classification societies as well as ISO standards, can help to quickly solidify norms around UMV operation. UMVs are already revolutionizing ocean operations. Regulation must catch up to ensure development continues and to prevent unintended consequences.